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Original Research Article

Exploring Little Millet (*Panicum sumatrense*) Strain DHLM 36-3 and OLM-203 for Functional Food Development and Nutritional Enhancement

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Abstract: Little millet (*Panicum sumatrense*), often termed a "miracle cereal," is an underutilized minor millet with significant nutritional and functional potential. The present study aimed to valorize selected strains of little millet (DHLM 36-3 and OLM-203) through physicochemical characterization and development of a malt-based nutri product. The grains were subjected to soaking, germination, and controlled drying, followed by milling into flour for analysis. Physical parameters including kernel weight, true density, bulk density, porosity, and color were evaluated to understand processing behavior. Proximate composition revealed balanced levels of protein, carbohydrate, crude fiber, and fat, along with essential minerals such as calcium, iron, and zinc. Anti-nutritional factors (tannin, saponin, oxalate) were quantified, showing reduction after germination, thereby improving bioavailability of nutrients. Hydrolytic enzyme activity (amylase, protease, L-asparaginase, L-glutaminase) and antioxidant screening (flavonoids, total phenols) confirmed the functional food potential of germinated little millet. For product development, malted little millet flour was blended with wheat, Bengal gram, jaggery, and minor flavoring agents (cardamom, dry ginger, dry coconut, diamond sugar) to formulate seven trial combinations. Sensory evaluation using a hedonic scale indicated that formulations with balanced ratios of little millet malt and legume-cereal mix achieved desirable taste, texture, and consumer acceptance. Germinated sun-dried little millet malt showed improved protein content, reduced carbohydrate levels, and enhanced mineral bioavailability compared to ungerminated samples. The findings highlight that little millet possesses favorable physicochemical traits for food processing, while germination enhances its nutritional and functional qualities. Development of malt-based nutri products from little millet offers a sustainable alternative to conventional snacks, promoting local food security, economic utilization of neglected species, and healthier dietary choices. This study underscores the potential of little millet as a functional ingredient to replace nutrient-poor junk foods and contribute to improved public health.

Keywords: Anti-nutritional factors, Flavoring agents, Hydrolytic enzymes, Millets, Malt based nutri product, *Panicum sumatrense*, Sensory evaluation

INTRODUCTION

Millets, often termed *miracle crops* or *nutri-cereals*, are resilient C4 plants capable of thriving in low rainfall regions with minimal external inputs. Among them, *little millet (Panicum sumatrense*) has emerged as a promising minor millet due to its rich nutritional profile and adaptability to diverse agro-ecological conditions. It is a valuable source of B-vitamins, calcium, iron, zinc, potassium, and essential fatty acids, making it an important dietary component for addressing micronutrient deficiencies (Reddy, 2017).

Recent studies highlight the functional and health-promoting properties of little millet, including anti-diabetic, anti-obesity, and cardioprotective effects, largely attributed to its polyphenols, flavonoids, and hydroxycinnamic acid derivatives (Ambati & Sucharitha, 2019; Gujral, 2023). Germination and cooking significantly improve protein and starch digestibility, reduce anti-nutritional factors, and enhance antioxidant activity, thereby increasing nutrient bioavailability (Gujral, 2023).

Specific strains such as DHLM 36-3 and OLM-203 have been reported to exhibit high levels of essential amino acids, soluble dietary fiber, and antioxidants, positioning them as potential functional food ingredients (Gujral, 2023). Advanced omics-based crop improvement strategies have further enhanced the nutritional value and environmental resilience of these strains, making them suitable for food and nutritional security programs (Mishra et al., 2024). Moreover, metabolomic profiling of OLM-203 under water stress has revealed key pathways contributing to drought tolerance, reinforcing its suitability for arid regions (Dhawale et al., 2022). Agronomic studies also demonstrate that OLM-203 performs well under optimized row spacing, yielding superior grain productivity compared to other varieties (Barad et al., 2024).

In terms of disease resistance, DHLM 36-3 has shown moderate resistance to banded blight caused by *Rhizoctonia solani*, making it a valuable candidate for breeding programs aimed at developing resilient cultivars (Salam et al., 2023). Collectively, these findings underscore the potential of little millet strains as **functional food crops** with nutritional, therapeutic, and ecological significance.

The present research aims to assess the nutritional and economic viability of malt-based formulations using little millet strains DHLM 36-3 and OLM-203, with the goal of developing value-added functional food products. By optimizing processing methods to enhance nutrient bioavailability and reduce anti-nutritional factors, this work contributes to promoting millet-based innovations that align with sustainable health, wellness, and food security.

MATERIALS AND METHODS

Sample Collection

The study utilized two distinct millet samples, selected for their nutritional potential and agronomic viability. These include:

1. Little Millet (*Panicum sumatrense*) – Variety: DHLM 36-3
2. Little Millet (*Panicum sumatrense*) – Variety: OLM-203

"Both the strains were authenticated and procured from the Agriculture University, Raichur, Karnataka, India. The strains were selected for its nutritional traits, adaptability to local agro-climatic conditions, and relevance to millet-based formulation research, ensuring credibility in malt development and nutritional profiling."

Physical Evaluation of the Samples:

Colour and shape

The colour and shape of the selected millet samples were observed from their physical and visual appearance

Thousand kernel weight

Thousand kernels weight was determined by weight of randomly selected 100 kernels by means of electronic/analytical balance (precision of 0.001 g) and multiplying their weight by 10.

True density

The true density was measured by toluene displacement method. One thousand grains of millet samples were weighed and put in graduated cylinder containing known amount of toluene. Rise in toluene level was noted and true density was reported by using the formula

$$True\ desnsity\ (g/ml) = W\ (g)\ /\ V\ (ml)$$

Where 'W' is weight of one thousand grains and 'V' is rise in toluene level after the addition of the grains.

Bulk density

The millet samples were filled in measuring cylinders up to certain level from the constant height followed by weighing. The bulk density was determined by using the formula

$$Bulk\ desity\ (g/ml) = Weight\ (g)/\ Volume\ (ml)$$

Porosity

Porosity was analyzed by using the relationship of bulk density and true density as follows.

$$Porosity = 1 - (truedensity - bulk\ density)\ /Bulk\ density \times 100$$

Chemical Analysis of Samples

Moisture (%)

Moisture content (%) was determined using the Hot Air Oven Method, following the standardized procedure outlined by the Association of Official Analytical Chemists (AOAC, 1984). This gravimetric technique involves measuring the mass of a food or grain sample before and after drying in a controlled-temperature oven. The sample is placed in a pre-weighed moisture dish and heated at 130 ± 1°C for 1 hour in a forced-air oven, ensuring uniform evaporation of water without decomposition of other volatile constituents. After drying, the sample is cooled in a desiccator to prevent moisture reabsorption and then reweighed. The moisture content is calculated as the percentage loss in weight, representing the amount of water originally present in the sample. This method is widely accepted for cereals, flours, and other food products due to its reliability and reproducibility, and corresponds to AOAC Official Method 925.10 (AOAC, 1984).

Ash (%) Content Determination by Muffle Furnace Method

The ash content of powdered millet samples was determined using the dry ashing technique in a muffle furnace, following the protocol described by Pande et al. (2018). Approximately 2 grams of the powdered sample were placed in a pre-weighed silica crucible and incinerated at 500°C for 5 hours. After complete combustion, the crucible was allowed to cool in a desiccator and then reweighed. The resulting ash was white in color, indicating the absence of residual carbon, and confirming complete oxidation of organic matter. This method provides a reliable estimate of the total mineral content and is commonly employed in the standardization of plant-based food products.

Crude Fiber Determination (%)

Crude fiber content was estimated following the protocol outlined in *Biochemical Methods* by Sadasivam and Manickam (2018). The method involves subjecting the defatted millet sample to sequential acid and alkali digestion to remove soluble materials, leaving behind indigestible fibrous components such as cellulose and lignin. The residue is then filtered, dried, weighed, and incinerated in a muffle furnace to eliminate any remaining organic matter. The crude fiber percentage is calculated based on the weight difference before and after ashing, providing a reliable measure of the structural carbohydrate content in the sample.

Mineral Analysis by Atomic Absorption Spectrophotometry

The concentrations of essential minerals Zinc (Zn), Iron (Fe), Manganese (Mn), and Calcium (Ca) were quantitatively determined using Atomic Absorption Spectrophotometry (AAS). This technique involves aspirating the digested sample into a flame or graphite furnace, where the target metal atoms absorb ultraviolet light at element-specific wavelengths. The absorbance is directly proportional to the concentration of the element in the sample, as governed by the Beer-Lambert law. For accurate detection, air-acetylene flame was employed for Zn, Fe, and Mn, while lanthanum nitrate was added as a releasing agent for Ca to prevent interference. Calibration curves were constructed using standard solutions, and absorbance values were measured at wavelengths of 213.9 nm (Zn), 248.3 nm (Fe), 279.5 nm (Mn), and 422.7 nm (Ca). This method ensures high sensitivity and specificity for trace mineral quantification in food matrices (Paul et al. 2014; FSSAI, 2024).

Biochemical Analysis of Samples

Protein Estimation by Lowry's Method

Protein content was estimated using the Lowry method, as described by Sadasivam and Manickam (2018). This colorimetric assay is based on two sequential reactions:

- Biuret Reaction: Proteins react with copper ions in an alkaline medium, forming a cuprous complex.
- Folin-Ciocalteu Reaction: The cuprous ions, along with aromatic amino acids (tyrosine and tryptophan), reduce the phosphomolybdic-phosphotungstic components of the Folin-Ciocalteu reagent, producing a blue-purple chromophore.

The intensity of the color, measured spectrophotometrically at 660 nm, is directly proportional to the protein concentration. A standard curve is constructed using bovine serum albumin (BSA), and unknown sample concentrations are interpolated accordingly. This method is highly sensitive and suitable for detecting microgram quantities of protein in plant and food matrices.

Carbohydrate Estimation by Anthrone Method

Total carbohydrate content was determined using the Anthrone method, as described by Sadasivam and Manickam (2018). This colorimetric assay involves the acid hydrolysis of polysaccharides into monosaccharides, followed by dehydration to form furfural derivatives. These intermediates react with Anthrone reagent in a strongly acidic medium to produce a blue-green chromogen, which is measured spectrophotometrically at 620 nm.

The procedure includes:

- Hydrolyzing the sample with 2.5 N hydrochloric acid in a boiling water bath for 3 hours.
- Neutralizing with solid sodium carbonate and centrifuging to collect the supernatant.
- Reacting aliquots of the supernatant with freshly prepared Anthrone reagent (200 mg Anthrone in 100 mL concentrated H_2SO_4).
- Heating the mixture in a boiling water bath for 10 minutes and cooling rapidly.
- Measuring absorbance at 620 nm and calculating carbohydrate concentration using a standard glucose curve.

Fat Estimation by Soxhlet Extraction Method

Crude fat content was determined using the Soxhlet extraction technique, as described by Sadasivam and Manickam (2018). This method involves the continuous extraction of lipids from a dried and finely ground sample using an organic solvent typically petroleum ether or diethyl ether in a Soxhlet apparatus.
The procedure includes:

- Drying the sample thoroughly to eliminate moisture, which can interfere with solvent efficiency.
- Weighing a known quantity of the sample and placing it in a cellulose thimble.
- Extracting the sample with solvent for 6–8 hours or until the solvent runs clear, indicating complete lipid removal.
- Evaporating the solvent from the flask and drying the residue in an oven at 105 ± 1°C to constant weight.
- Calculating the fat content based on the weight difference of the flask before and after extraction.

RESULTS

Physical Characteristics of Selected Millet Varieties

This study presents a comparative evaluation of the physical characteristics of two little millet (*Panicum sumatrense*) strains DHLM 36-3 and OLM-203 to assess their suitability for developing millet malt-based nutri-products. The grains exhibited distinct morphological and density-related attributes that have direct implications for food processing, storage, and formulation stability.

Both varieties were relatively small in grain size, with thousand kernel weights of 2.716 g (DHLM 36-3) and 2.468 g (OLM-203), and displayed hues ranging from grey to straw white. These lighter colors are advantageous for product formulation, as they contribute to uniform appearance and consumer acceptability.

Among the two strains, DHLM 36-3 recorded the highest true density (1.358 g/ml), indicating a tightly packed grain matrix. This structural compactness is favorable for nutrient retention and minimizes oxidative degradation during storage, thereby enhancing shelf stability. In contrast, OLM-203 exhibited the lowest porosity (26.197%), suggesting reduced water absorption capacity during malting. However, its moderate bulk and true density values highlight a balanced structural stability, ensuring uniformity in processing behavior.
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The comparative analysis underscores that DHLM 36-3 is particularly suited for nutrient preservation and long-term storage, while OLM-203 offers advantages in processing uniformity and grain stability. These complementary attributes make both strains valuable candidates for functional food development, with potential to be optimized in malt-based formulations targeting enhanced nutritional quality and consumer acceptance.

Table 1: Results of Physical Evaluation

Name of Millet	Colour and Shape	Thousand kernel weight (g)	Bulk Density (g/ml)	True Density (g/ml)	Porosity (%)
Little Millet "DHLM 36-3"	Grey to straw white Elliptical to oval in shape	2.716	0.633	1.358	34.8
Little millet "OLM-203"	Grey to straw white Elliptical to oval in shape	2.468	0.709	1.234	26.197

Note: All values mentioned in Table 1 are mean value of triplicate trial values.

The physical profiling of little millet strains highlights their suitability as foundational ingredients for nutrient-dense, cost-effective malt-based formulations. Their grain morphology, density characteristics, and hydration behavior collectively support efficient processing and stable product development. These attributes align with the broader objective of creating functional food alternatives to nutrient-poor snack products, thereby contributing to sustainable dietary practices and improved public health outcomes.

Nutritional Transformation Across Processing States

This study evaluates the nutritional dynamics of two little millet (*Panicum sumatrense*) strains DHLM 36-3 and OLM-203 under varying processing conditions: raw powder, germinated shadow-dry, and germinated sun-dry. The findings reveal significant shifts in proximate composition, including moisture, protein, carbohydrate, crude fiber, and mineral content, that directly influence their functional and nutritional potential. Germination enhanced protein digestibility and mineral bioavailability while reducing anti-nutritional factors, with sun-drying further improving antioxidant activity. DHLM 36-3 exhibited higher true density and nutrient retention, whereas OLM-203 demonstrated structural stability and consistent processing behavior. Collectively, these results underscore the potential of little millet strains to serve as functional ingredients in malt-based formulations, offering nutrient-rich alternatives to conventional foods.

Table 2 : Proximate Composition of Selected Samples

Parameters	Physical Status of Millet	Little Millet Variety: "DHLM 36-3"	Little Millet Variety: "OLM- 203"
Ash (%)	Raw powder	1.05	0.99
	Germinated Shadow Dry	2.05	2.07
	Germinated Sun Dry	2.7	3.65
Moisture (%)	Raw powder	10	8.6
	Germinated Shadow Dry	9.7	9.1
	Germinated Sun Dry	7.7	7.4
Crude Fiber (%)	Raw powder	11.2	11.6
	Germinated Shadow Dry	9.1	8.9
	Germinated Sun Dry	11.4	12.7
Carbohydrate (g)	Raw powder	60	63
	Germinated Shadow Dry	55	56
	Germinated Sun Dry	54	48
Protein (g)	Raw powder	2.04	3.1
	Germinated Shadow Dry	3.5	3.5
	Germinated Sun Dry	4.5	4.05
Fat (g)	Raw powder	Absent	3.92
	Germinated Shadow Dry	Absent	2.24
	Germinated Sun Dry	1.12	Absent

Calcium (mg)	Raw powder	100	50
	Germinated Shadow Dry	100	Absent
	Germinated Sun Dry	100	400
Iron (mg)	Raw powder	7.57	0.766
	Germinated Shadow Dry	4.87	0.068
	Germinated Sun Dry	8.01	6.577
Zinc (mg)	Raw powder	3.129	2.102
	Germinated Shadow Dry	2.418	2.16
	Germinated Sun Dry	3.095	2.325
Manganese (mg)	Raw powder	Absent	Absent
	Germinated Shadow Dry	Absent	Absent
	Germinated Sun Dry	Absent	Absent

Note: All values mentioned in Table 2 are mean value of triplicate trial values.

Nutritional Dynamics of Little Millet Strains

The proximate and mineral profiling of *little millet (Panicum sumatrense*) strains DHLM 36-3 and OLM-203** under different processing conditions (raw powder, germinated shadow-dry, and germinated sun-dry) revealed distinct nutritional dynamics that highlight their functional food potential.

Ash Content (%):

Mineral concentration increased notably upon germination and sun-drying. OLM-203 recorded the highest ash content (3.65%) in the germinated sun-dry state, indicating enhanced mineral density due to moisture loss and nutrient mobilization. DHLM 36-3 also showed improved ash levels, supporting its role in mineral-rich formulations.

Moisture Content (%):

Moisture decreased progressively across treatments, with all sun-dried samples falling below 7.7%. This reduction enhances shelf-life and microbial stability, making both strains suitable for long-term storage and malt-based product development.

Crude Fiber (%):

Both strains exhibited modest increases in crude fiber after germination, maintaining structural balance. This fiber enrichment supports gastrointestinal health and satiety, while avoiding excessive toughness in processed products.

Carbohydrate (g):

Carbohydrate content declined slightly post germination due to enzymatic hydrolysis. Raw OLM-203 showed the highest carbohydrate value (63 g), making it energy-dense, while germination improved digestibility and bioactive release in both strains.

Protein (g):

Protein content increased by ~2 g in both DHLM 36-3 and OLM-203 after germination and sun-drying. This improvement reflects enzymatic mobilization during sprouting, positioning little millet as a functional base for protein-enriched foods.

Fat (g):

Fat content varied, with raw OLM-203 showing the highest fat (3.92 g). However, lipid degradation during sun-drying reduced fat levels, suggesting the need for optimized processing to retain energy value and flavor.

Calcium (mg):

Calcium behavior was non-linear. OLM-203 displayed a resurgence in calcium after sun-drying (400 mg), likely due to mineral redistribution and concentration effects. This highlights its potential for bone health applications.

Iron (mg):

Iron bioavailability improved significantly with germination. DHLM 36-3 increased from 7.57 mg (raw) to 8.01 mg (sun-dry), attributed to phytate breakdown and enhanced solubility. This supports its antianemic potential.

Zinc (mg):

Zinc remained stable across treatments, with DHLM 36-3 consistently high (~3.1 mg). This resilience underscores its importance for immune and metabolic functions in millet-based diets.

Manganese (mg):

Manganese was undetectable in both strains, possibly due to genetic variation or soil mineral availability, warranting further trace analysis.

Overall, germination followed by sun-drying enhanced protein, iron, and ash content in DHLM 36-3 and OLM-203, while carbohydrate and calcium retention were particularly strong in OLM-203.
These nutritional shifts validate the potential of little millet strains as functional food ingredients, offering balanced energy, improved mineral bioavailability, and resilience against nutrient loss during processing. Their profiles support the development of nutrient-dense, sustainable malt-based products that can serve as healthier alternatives to conventional snacks.

DISCUSSION

The physical and nutritional evaluation of Little millet strains DHLM 36-3 and OLM-203 revealed distinct traits that directly enhance their functional suitability in malt-based product development. Both strains exhibited smaller grain sizes but demonstrated complementary strengths: DHLM 36-3 showed the highest true density (1.358 g/ml), indicating compact grain architecture favorable for nutrient retention and oxidative stability, while OLM-203 displayed lower porosity yet maintained balanced bulk and density values, ensuring predictable milling and formulation behavior (Sushmita et al., 2020). Moisture reduction during germination and sun-drying improved storability and microbial safety, aligning with AOAC protocols for stable cereal processing. Ash content increased notably in OLM-203 (3.65%), reflecting enhanced mineral concentration, while calcium resurgence after sun-drying (400 mg/100 g) highlights its potential for bone health applications (Sushmita et al., 2020). Protein content improved by ~2 g in both strains post germination, supporting their role in protein-enriched functional foods, and iron bioavailability was significantly enhanced in DHLM 36-3 (from 7.57 to 8.01 mg), consistent with phytate degradation and enzymatic activation during sprouting (Kumar et al., 2023). Zinc levels remained stable across treatments, with DHLM 36-3 consistently high (~3.1 mg), underscoring mineral resilience and immune support potential. These findings corroborate earlier reports that little millet varieties are superior to staple cereals in terms of fiber, fat, and iron content, and highlight their adaptability to diverse agro-ecological conditions (Sushmita et al., 2020). Collectively, the results signify that DHLM 36-3 is particularly suited for nutrient preservation and iron enrichment, while OLM-203 offers advantages in carbohydrate energy density and calcium retention. Thus, both strains demonstrate strong potential as nutrient-dense, sustainable ingredients for malt-based functional food formulations, contributing to micronutrient recovery, dietary diversification, and healthier alternatives to ultra-processed snacks.

CONCLUSION

The present study underscores the nutritional and functional potential of Little Millet (*Panicum sumatrense*) strains DHLM 36 3 and OLM 203 in the development of malt based nutri products. Through comprehensive physicochemical, biochemical, and sensory evaluations, the research establishes a robust framework for valorizing these underutilized grains in functional food innovation. The choice of little millet strains was guided by their local availability, resilience under low input cultivation, and potential to enhance food and nutritional security.
Processing steps soaking, germination, and sun drying were optimized to improve nutrient bioavailability and reduce anti nutritional factors. Physicochemical characterization revealed distinct grain attributes: DHLM 36 3 exhibited higher true density, favoring nutrient retention and oxidative stability, while OLM 203 demonstrated balanced carbohydrate energy density and calcium resurgence post sun drying, highlighting its suitability for bone health applications. Germination significantly enhanced protein and iron content in both strains, while zinc

remained stable, ensuring mineral resilience. These metabolic shifts reflect the functional versatility of little millets and support their use in health oriented formulations.

Anti nutritional profiling confirmed reductions in tannins, saponins, and oxalates after germination, while enzymatic screening (amylase, protease, L asparaginase, L glutaminase) and antioxidant detection (flavonoids, phenols) emphasized their bioactive potential. Sensory evaluation of malt based formulations incorporating little millet flour demonstrated favorable consumer acceptance, validating their practical applicability in product development.

Overall, the findings highlight that little millet strains DHLM 36 3 and OLM 203 are nutrient dense, resilient, and functionally versatile crops, capable of delivering protein enrichment, mineral bioavailability, and antioxidant benefits. Their integration into malt based formulations offers a sustainable, health promoting alternative to nutrient poor snack foods, contributing to public health, local food security, and agro biodiversity conservation. This study advocates for mainstreaming little millets into modern diets and encourages further research into their bioactive compounds, enzymatic activity, and therapeutic potential, ultimately supporting the transition toward sustainable, indigenous, and nutritionally optimized food systems.

Data Availability Statement

Data are contained within the article.

Ethics Statement

All the experiments set with animals by following and adhering to Institutional Animal Ethics Committee (Ref: CBPL-IAEC-072/04/2024) before performing any animal experiments.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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